CHAPTER 1 - INTRODUCTION

1-01. AUTHORITY

1-01.01 This report was authorized by the 1954 annual conference of the Snow Investigations of the Corps of Engineers, U. S. Army, held in offices of the North Pacific Division on 13-14 May 1954. Pertinent sections of paragraph 4 of the notes from that conference, as revised, are quoted for information: "The principal feature of the proposed plan of future work was the completion within the next two years of a publication which would summarize all present knowledge of the Snow Investigations Unit. It was decided that an editorial committee should be formed to prepare an outline and specifications for the report. F. F. Snyder, W. L. D. Bottorf, and D. M. Rockwood (Chairman) were designated as members of that committee. After completion of the outline and specifications, it should be circulated among the participating offices for comment..."

1-01.02 In accordance with the above-quoted directive, an outline of material to be presented in the report was prepared during the summer of 1954 and submitted to the editorial committee for review. The outline was reviewed in detail at the periodic conference, Snow Investigations, held on 4 November 1954 at the North Pacific Division office. Suggested revisions were incorporated in a revised outline, which has been closely followed in this report.

1-02. PURPOSE AND SCOPE OF REPORT

1-02.01 This report is designed to be a reference volume for hydrologists. The Cooperative Snow Investigations, since the time of its organization, has dealt with the analysis of individual snow hydrology problems. Their solutions, when combined and integrated, form the technical background for the report as a whole. It is the intent, therefore, to present pertinent results of investigations accomplished to date and to indicate how they apply in solution of snow hydrology problems that arise in work of the Corps of Engineers. Specific purposes are as follows:

a. To make available to hydrologists a comprehensive report which summarizes all present knowledge of the Snow Investigations Unit with regard to (1) deposition and distribution of the snowpack and the depletion of snow cover, (2) evaluation of the hydrologic water balance of basins where appreciable snow occurs, (3) the physics of snowmelt, (4) the storage and transit of liquid water in the snowpack, and (5) possible methods for estimating rates of streamflow and volumes of runoff in basins where snow affects those quantities.

b. To point out gaps in existing knowledge of snow hydrology and suggest ways of filling them.

1-02.02 It is the intent that the report be suited primarily to an engineering approach to snow-hydrology problems, in order that solutions may be developed for project basins from data commonly available. However, a reasonably sound theoretical background for the hydrologist is believed essential, in order that he may formulate short cuts and approximations without significant departure from fundamental laws. Accordingly, the report deals with both theory and applications, but emphasis is placed on presentation of relationships which may be used by hydrologists in their practical work.

1-02.03 The report embraces all pertinent analyses from prior publications of the unit, as well as its unpublished analyses and certain pertinent work done by other investigators. In general, the extraction of materials is fairly brief, but is in sufficient detail that hydrologists without previous experience in the analysis of snow problems can gain a working knowledge of the field. It is assumed that the reader has access to a set of the previously published reports; accordingly, most basic data and certain detailed analyses contained therein, though considered useful supplementary material, are referred to without the necessity of repetition in this volume.

1-03. INITIATION, OBJECTIVES, AND ACTIVITIES OF THE SNOW INVESTIGATIONS

1-03.01 General. - For several years prior to 1945, problems encountered by the Corps of Engineers in determining spillway design floods and by the Weather Bureau in meeting its responsibilities for streamflow forecasting gave rise to discussions relative to initiating an integrated investigational program in snow hydrology. As a result, in 1945 the Corps of Engineers and the Weather Bureau formulated a joint research program, organized as the Cooperative Snow Investigations and pointed initially toward solution of hydrologic problems pertinent to mountain regions of western United States. Over-all administration was placed with the Division Engineer, South Pacific Division (then Pacific Division), Corps of Engineers, at San Francisco, California, where the office of the Program Director, which included a Processing and Analysis Unit and a Technical Supervisor, was established. Assistance to the program was provided to a limited degree by three other Federal agencies, the Geological Survey, Bureau of Reclamation, and Forest Service. The Snow, Ice, and Permafrost Research Establishment of the Corps of Engineers provided assistance to the program for the years 1950 through 1953, particularly with regard to field observations made at the Central Sierra Snow Laboratory. Occasional assistance was provided by other organizations, such as state and local agencies and private research organizations. Direct participation in the program by the Weather Bureau ended in 1952. Thereafter, the research was continued under the name "Snow Investigations" by the Corps, but the

basic program objectives remained unchanged. In June 1953 the administration of the program was transferred from the South Pacific Division to the North Pacific Division office of the Corps of Engineers, and program personnel and records were moved to Portland, Oregon. Reference is made to the Progress Reports (see Appendix I) for detailed descriptions of year-to-year progress of the investigations.

1-03.02 Objectives. - The direction of the work has been focused according to the broad objectives of the program, which were set forth initially as follows:

a. Determination of a practicable and reliable method of evaluating the maximum streamflow which may be produced by a watershed as the result of snowmelt or combined snowmelt and rain.

b. Development of a practicable and reliable method of forecasting seasonal and short-term streamflow, including floods, resulting from snowmelt or combined snowmelt and rain.

c. Expansion of basic knowledge of hydrodynamic and thermodynamic characteristics of snow through a program of fundamental scientific research.

d. Advancement of knowledge of meteorological, climatological, and hydrological phenomena as they influence the above three objectives.

These broad objectives have remained unchanged throughout the duration of the program. However, emphasis on various phases of the work has shifted from time to time. Initially, the emphasis was upon processing and compilation of the basic data from the snow laboratories. During the intermediate period, considerable time was spent on development of fundamental scientific research. More recently, work on application of methods to indicate hydrologic conditions on snow laboratory basins and project basins has received a proportionally larger share of the effort of the unit.

1-03.03 Field operations. - The field operation phase of the program consisted primarily of the operation of three snow laboratories with different environments in the mountains of western United States. Chapter 2 describes in detail the laboratories, the observations made, and the pertinent data gathered and published. The laboratories were operated for periods ranging from 5 to 8 years each, and records were generally concurrent. The purpose of the operations was to determine and measure the physical factors affecting snow hydrology, and also to evaluate variations of certain of these quantities over the laboratory drainage basins, which consisted of relatively small areas, ranging from 4 to 21 square miles. The laboratories also were used for the investigation of special techniques for evaluating and reporting snow conditions from remote mountain areas, and were designed to serve as pilot areas whereby

methods of basin application of hydrologic principles could be tested, with sufficient instrumentation to assure reasonable delineation of the variation in basin amounts from point measurements. The operation of each of the laboratories required the provision of living facilities for 5 to 10 men and facilities for maintenance of equipment and instruments. Each laboratory was located in a headwaters area where rugged terrain and severe climate necessitated a large expenditure of effort to meet minimum living requirements and perform periodic visits to the instruments. Over-snow vehicles were provided and were used when feasible, but much of the travel was done on foot. All records, either in the form of automatic recorder charts or spot observations of hydrometeorological elements, were sent directly to the Processing and Analysis Unit of the Cooperative Snow Investigations.

1-03.04 Data processing. - The processing and publishing of records from the laboratories also constituted a major task. In all, there were some 1,500,000 observations published in final form in hydrometeorological logs. This mass of data required the preparation of a manual to insure standard methods of reducing original recorder charts to usable data. At the time of maximum output in the processing unit, 30 individuals were working on the several phases of data reduction. Approximately one-third of the data was entered on individual punch cards for aiding in compilation of tabular data and for expediting analytical studies. All original records were microfilmed. The hydrometeorological logs for each laboratory were published by water years; each log averaged approximately 200 pages. In addition to data tabulations, the logs included brief descriptions of instrumentation, site characteristics, and a basin map. The hydrometeorological logs were given general distribution to cooperating agencies and scientific organizations both in this country and abroad.

1-03.05 Analytical work. - The analytical phase of the Cooperative Snow Investigations actually commenced with the inauguration of the program. Technical Report No. 6-1, dated 10 March 1947, consists of a classified outline of the analytical program. The outline is in five major sections and includes a list of over 200 analytical projects which were proposed on the basis of examination of the literature, consultation, and logical classification of then-known requirements in order to meet program objectives. The analytical program outline was intended as a comprehensive listing of fields of research in problems related to snow hydrology, and served as a guide from which priorities of studies could be established. During the period from 1947 to 1950, many of the analytical projects were investigated in an exploratory manner, but few reports were issued on analytical work. During this time, much of the effort was required for orientation of personnel in snow-hydrology problems, because the field was, for the most part, unexplored. Also, due to the fact that laboratory data reduction was not complete but was proceeding concurrently with the analytical work, much of time was spent in the processing of field data. While many of the studies performed during this time were not fruitful in producing

usable relationships, the work was of value in suggesting future lines of approach, and expansion or modification of the laboratory program was made as investigations progressed, to provide bases for improvement of instruments and observational techniques and schedules. Beginning in 1950 the analytical work was directed primarily to problems related to development of methods and relevant criteria for determining maximum-type floods involving snowmelt. In general, these methods are also applicable to problems involved in project operation. The results of these investigations have been published in the form of Research Notes and Project CW-171 Technical Bulletins which have been given limited distribution.

1-03.06 Organization and administration of the Cooperative Snow Investigations. - Formulation and general direction of the program was provided through policy-making conferences--usually held annually, but occasionally more frequently for special requirements--which were attended by participating-office representatives at the several levels of responsibility for both the Corps of Engineers and the Weather Bureau. At these conferences, the work was reviewed, and over-all planning of activities, both technical and administrative, was developed. Specific direction of the program as a whole rested with the Program Director, a Corps of Engineers employee, to carry out the plans formulated by the conference. The Program Director supervised the operation of the field laboratories as well as the Processing and Analysis Unit. Until 1950, a Technical Supervisor was responsible for direction of the technical phases of laboratory operation, conducting of special experiments in the field, and development of instrumentation. Plate 1-1 is an organization chart which shows the channels of authority that existed between the various Weather Bureau and Corps of Engineers offices, and the Cooperative Snow Investigations activities. This organization applied essentially from 1947 through 1950 fiscal years. In 1950 the program was reorganized, and field work was curtailed at the laboratories. Under the reorganization, the Weather Bureau and the Corps of Engineers established analysis units under their respective organizations to pursue problems in their fields of responsibility, but coordination was continued. Special emphasis was directed toward processing and publishing laboratory data in final form. Although after 1950 the large-scale operation of the laboratories was discontinued, an intensive program of special observations was carried on directly by groups of analysts temporarily detailed from the unit to obtain information essential to the analytical work. Key administrative and technical supervisors during the entire period are listed below:

Program Director

W. F. Bingham, Corps of Engineers,	1944-1945
W. C. Cassidy, Corps of Engineers,	1946
F. L. Rhodes, Corps of Engineers	1947-1950
W. L. D. Bottorf, Corps of Engineers,	1950-1953
D. M. Rockwood, Corps of Engineers,	1953-1956

Technical Supervisor

R. W. Gerdel, Weather Bureau,	1946-1950

Processing and Analysis Unit

W. T. Wilson, Weather Bureau, (Chief)	1946-1950
D. H. Miller, Corps of Engineers, (Asst.)	1946-1950

Head, Corps of Engineers Civil Works Investigation Project 171

D. W. Hullinghorst	1949-1951
C. E. Hildebrand	1951-1956

Supervisor of Special Field Observations

P. B. Boyer	1951-1954

Direction of the individual laboratories is described in chapter 2 of this report. Cooperative Snow Investigations personnel (exclusive of laboratory personnel), whose tenure was in excess of one year, are listed in table 1-1.

1-03.07 Coordination with other agencies and research organizations. - Snow research is carried on by various agencies and research groups, and results of studies have been published in technical journals and reports, both in the United States and in foreign countries. The Cooperative Snow Investigations has maintained contact with those organizations with which it is familiar, either directly or through the literature. This coordination falls into three categories, as follows: (1) direct cooperation by Federal agencies or special research groups with the Cooperative Snow Investigations; (2) participation of members of the Snow Investigations in the activities of technical societies whose objectives are directed toward snow or hydrologic research; and (3) informal discussions with individuals or representatives of organizations for exchange of ideas on snow hydrology.

1-03.08 Direct cooperation from Federal agencies began with the initiation of the program. Shortly after formulation of the cooperative program by the Corps of Engineers and the Weather Bureau, the Bureau of Reclamation and the Geological Survey each provided the services of one or two employees for a period of from two to four years. The Forest Service contributed primarily to the laboratory phase of the work, and cooperated on a reimbursable basis in a number of aerial flights for obtaining photographs of snow-covered areas. The Forest Service also supplied information on mountain soils and forest effects on the snowpack. The U. S. Air Force made aerial photographs and provided access to weather data and charts. The Snow, Ice and Permafrost Research Establishment maintained close liaison with the unit in operation of the Central Sierra Snow Laboratory, exchange of data, and consultation on analytical work. A contract was negotiated with the University of California for the purchase of two Gier-Dunkle radiometers

for measuring heat transfer to the snowpack by radiation. Members of the university faculty were most helpful in providing technical advice on application of these instruments to snowpack work. Other phases of cooperative effort at the Central Sierra Snow Laboratory were with the U. S. Navy Electronics Laboratory for testing an automatic weather station and with the Landing Aids Experiment Station for studying the performance of lighting equipment to be used for aircraft landings. In connection with the development of the radioisotope-radiotelemetering snow gage, a contract for the radio reporting equipment was negotiated with the Motorola Corporating which gave considerable aid in the radio transmission phase of development of the gage. A more complete discussion of cooperation in the field investigations is contained in chapter 2.

1-03.09 Members of the Cooperative Snow Investigations have, from time to time, participated in technical society functions, either by submitting technical papers or providing formal or informal discussions of work by others. These societies include: (1) American Geophysical Union, (2) American Meteorological Society, (3) American Society of Civil Engineers, (4) International Union of Geodesy and Geophysics, and (5) Western Snow Conference. Many of the staff were members of one or more of the above organizations. In addition to the above, there were miscellaneous discussion groups and conferences through which staff members have contributed information on various activities of the program. These include interagency committees and work groups, educational organizations, and special groups dealing with snow survey work.

1-03.10 Occasionally, representatives of private engineering organizations, commercial enterprises, universities, and hydrologic research groups contacted the unit informally or by letter and sought information on application of some phase of the work to specific problems. The Investigations Unit always attempted to provide the required information, within the limitations of available time.

1-03.11 Bibliographic material. - While the Cooperative Snow Investigations made no special attempt to review or list all published work on snow hydrology, a brief bibliography (Technical Report 13) was prepared, listing pertinent reference material available at the time of publication (1950). Abstracts of work done in this and related fields were reviewed periodically, and copies of papers of particular interest were obtained for review. The Transactions of the American Geophysical Union, Proceedings of the American Society of Civil Engineers, the various publications of the American Meteorological Society, and the Journal of Glaciology were the principal technical society publications utilized by the unit, but other scientific publications, including periodicals from a few foreign societies, were scanned for work done by others in the field of snow hydrology. The annotated Bibliography of Snow, Ice and Permafrost (SIPRE Report 12), published by the Snow, Ice and Permafrost Research Establishment has been

particularly helpful for reviewing the literature in the field of snow. The meteorological abstracts published by the American Meteorological Society similarly provided a convenient and comprehensive listing of meteorological literature.

1-04. THE PROBLEM OF SNOW HYDROLOGY

1-04.01 General. - The field of hydrology is concerned entirely with the evaluation of the various components of the hydrologic cycle. Quantitative evaluation of factors affecting each of these components requires a knowledge of certain phases of the sciences of meteorology, hydraulics, thermodynamics, geology, soil mechanics, and plant physiology.

1-04.02 Knowledge of meteorological factors is of primary importance in snow hydrology. In evaluating moisture inflow from the atmosphere, it is necessary to understand the mechanism of precipitation, the characteristics of airmasses and fronts, and general atmospheric circulation patterns. Meteorology is relied upon particularly in physical study of snowmelt, where energy exchange, both with the atmosphere and with the sun, as well as effects of the atmosphere on radiation exchange, must be generally understood. Fundamental knowledge of meteorology, therefore, is essential to understanding the problem of snow hydrology as a whole, since the atmosphere constitutes the source of moisture supply and also regulates the energy exchange within a basin, which in turn governs snowmelt rates.

1-04.03 Just as the atmosphere is a regulating device for the production of water available for runoff, so the snowpack, soil, underlying geologic formations, and forest cover act to retard runoff and affect the water balance of an area. Thus other basic sciences must be utilized to evaluate the effects of all influencing factors throughout the hydrologic cycle. Particular attention must be given to: (1) the hydraulics of flow, both in open channels and through various media, and the time rate of change of flow as described by routing procedures; (2) the effect of geological formations upon ground-water storage and ground-water flow; (3) the capacity of soils to transmit and store water, as well as to transfer heat to the snowpack; and (4) the ability of plants and forests to affect the deposition of snow, to transpire water to the atmosphere, and to influence energy transfer between the atmosphere and the snowpack.

1-04.04 Point relationships. - In applying the basic sciences in snow hydrology, it is necessary first to determine each component of the hydrologic cycle individually at a point, under stated conditions of environment. Such a determination usually requires the derivation of the proper mathematical relationships of the variables affecting each component, and the establishment of constants of proportionality in the form of coefficients. The relative magnitudes of the components must be taken into account, and emphasis must be placed on

the more important functions. In this regard, the relationships of snow hydrology may be expressed by rational mathematical procedures.

1-04.05 Areal relationships. - Having determined point values, the next step consists of utilizing these values to determine amounts and distribution over a basin area, with respect to environmental differences, as well as to time. This involves procedures which are much less exact and less rigorous than for point evaluations. It is impractical to attempt a point-by-point analysis in basin application; rather, it is necessary to deal with basin averages in major subdivisions of geography or environment, and also to deal with averages in time. This concept leads to the use of indexes to represent basin averages from individual point measurements. The application of indexes requires the intelligent use of knowledge gained in studies of evaluation of conditions at a point, and consideration of the physical character of the area involved. Since the use of indexes involves the theory of sampling and errors in measurement, statistical procedures may be employed to evaluate the reliability of estimates and also the weightings of individual factors. The random selection of indexes, without particular regard to representation of basin amounts by point measurement in attempting to improve the fit of historical data should be avoided. The relative reliability of indexes may be established, however, through proper utilization of statistical methods, if the factors being evaluated are selected in accordance with the theoretical considerations. This permits use of indirect methods of evaluation of basin amounts from observational data commonly available. The deficiencies of those methods should be recognized, and when the available data are inadequate to represent basin conditions, steps should be taken to obtain more adequate data.

1-04.06 Applications. - Insofar as the Corps of Engineers is concerned, the application of snow hydrology principles is confined to project design and project operation. In each case the problems involved are grouped into three main categories, as follows: (1) the evaluation of water stored in the snowpack, and its relation to the hydrologic balance; (2) evaluation of rates of melt, the physical causes of snowmelt, and methods of application to basin hydrology; and (3) effect of the snowpack on runoff, both from snowmelt and rain on snow. For project design, fixed sequences of meteorologic and hydrologic conditions are usually chosen, the choice depending primarily on the over-all functional requirements of the project. Project operation, on the other hand, requires evaluation of conditions at a specific time and forecasts of streamflow for both long and short periods. The procedures developed must be flexible, to facilitate adjustment for changing weather; the effect of possible meteorological events subsequent to the date of the forecast must be determined and separated from effects of preceding conditions. Also, the limitations imposed by inaccuracies in weather and streamflow forecasting must be taken into account in the derivation of reservoir regulation schedules and long range volumetric streamflow forecasts.

1-05. PRIOR REPORTS BY COOPERATIVE SNOW INVESTIGATIONS

1-05.01 Technical publications of the unit have been issued in the form of Technical Reports, Research Notes, Technical Bulletins for Project CW-171 and Miscellaneous Reports. A listing of all published reports is contained in Appendix I. Technical Reports consist of the hydrometeorological logs for the laboratories, annual progress reports of the Cooperative Snow Investigations, reports on subjects dealing with snow characteristics, brief bibliographies, and terrain characteristics of Central Sierra Snow Laboratory. Research Notes contain reports of studies performed by the analytical unit and deal with a variety of problems; preliminary in nature, they were designed to disseminate technical findings and procedures quickly to participating offices for comment and use. Technical Bulletins for Project CW-171 are informal presentations of analytical work completed under the project (see section 1-06). The subject matter for Technical Bulletins is principally basinwide in application, but there are, in addition, separate studies for the analysis of individual factors at a point. Included in Appendix I under the title (Miscellaneous Reports) are CSSL micrometeorological studies made by researchers of the SIPRE Analytical Unit of the Cooperative Snow Investigations during 1952-53, and three other reports of interest, not covered under the previous classifications.

1-05.02 Information as to availability of prior reports issued by the Cooperative Snow Investigations will be furnished upon request to the Division Engineer, North Pacific Division, U. S. Corps of Engineers, 210 Custom House, Portland 9, Oregon.

1-06. WORK DONE UNDER PROJECT CW-171

1-06.01 The Corps of Engineers Civil Works Investigations Project 171, entitled, "Criteria for Estimating Runoff from Snow Melt," (referred to herein as CW-171) was initiated in 1949 to aid in the rapid prosecution of analytical work to be used in connection with the design and operation of Corps of Engineers projects. The primary purpose of the project was to accelerate the development of criteria needed in estimating standard project floods, spillway design floods and similar engineering determinations, and to make it possible for engineers from Division and District offices to contribute to the over-all program while increasing their knowledge of the snowmelt problem. It was recognized that much of the work was within the objectives of the Cooperative Snow Investigations and would ultimately be accomplished under that program. The project was established, however, to disseminate quickly the results of preliminary investigations, prior to their subsequent publishing in more complete form. CW-171 has, as one of its further objectives, a program for training Division and District office hydrology personnel in the procedures developed in the Snow Investigations. The project also served for training the unit personnel in the practical application of these procedures to hydrology problems

encountered by the participating offices. Project Bulletin No. I, dated 8 July 1949, describes in detail the objectives and administrative regulations of the project. The work reported on in the 18 Technical Bulletins of CW-171 is summarized in later chapters of this report. Since the inception of CW-171, there have been over 50 visits of individuals from the participating offices. Pertinent information on each of the visits is listed in Appendix II.

1-06.02 Methods developed under CW-171 and the over-all program have been used wholly or in part in the derivation of design floods for the several Corps of Engineers projects, including a standard project flood for the Cougar Project, and spillway design floods in the Libby, Painted Rock, Pine Canyon, Mathews Canyon, Success, and Terminus projects. Problems in connection with development of operational procedures for Corps of Engineers projects have received considerable attention under CW-171. These problems include derivation of forecasting procedures for streamflow from snowmelt, both on a long-term volumetric basis and on a short-term, day-to-day rate basis. Some work has been done in developing operating-rule curves for projects where snow is a factor. Assistance was also rendered in the derivation of an interim operating procedure for Pine Flat Reservoir and the development of procedures for forecasting seasonal runoff volume for Lookout Point and Detroit Reservoirs by the water-balance method.

1-07. ORGANIZATION OF REPORT

1-07.01 In general, the material which follows in this report is presented in order of development of the subject of snow hydrology, namely: (1) review of the basic data available from snow laboratory operation; (2) evaluation of the water stored in the snowpack, and its relation to the hydrologic balance; (3) theoretical considerations of factors affecting snowmelt; (4) methods of application of snowmelt indexes to estimate basin melt; (5) description of snow-cover depletion and approximate relationships between snow cover depletion and ablation of the snowpack; (6) determination of factors affecting storage of liquid water in the snowpack and runoff therefrom; (7) application of techniques for evaluating snowmelt, rainfall, snow cover, and effect of the snowpack on runoff, and reconstitution of streamflow hydrographs; (8) application of techniques to design flood determinations; (9) application of the relationship of snow water and the hydrologic balance to seasonal runoff forecasting; and (10) application of procedures to reservoir regulation.

1-07.02 Reference material. - Since there is frequent reference to the past reports of the Cooperative Snow Investigations, they are treated separately from other source material in this report and are referenced directly in the text by title or number and listed in Appendix I. All reference material other than that published under the Cooperative Snow Investigations or Corps of Engineers Snow Investigations is listed at the end of each chapter under the appropriate chapter heading.

TABLE 1-1

COOPERATIVE SNOW INVESTIGATIONS EMPLOYEES EXCLUSIVE OF LABORATORY PERSONNEL 1/ 2/

Employee	Entered Duty	Separated
Allison, I. D.	1953	1956
Arnold, B. A.	1951	1953
Bayuk, M.	1948	1951
Berger, P.	1951	1953
Bertle, F. (USBR)	1946	1949
Bingham, W. F.	1944	1945
Bottorf, W. L. D.	1950	1953
Boyer, P. B.	1949	1956
Brecheen, K. G.	1948	1952
Cassidy, W. C.	1945	1946
Czuba, W.	1949	1951
Daniels, G. E.	1946	1952
Gerdel, R. W. (USWB) +	1946	1950
Hamilton, R.	1949	1950
Himmel, J. M.	1947	1952
Hildebrand, C. E.	1949	1956
Hullinghorst, D. W.	1949	1951
Humphrey, H. N.	1946 *	1953
Humphrey, M. N.	1946 *	1949
Jencks, C. E.	1947 *	1956
Kaemmerling, W. H.	1950	1952
Lewis, M.	1950	1953
Lopez, E.	1948	1949
Mark, E.	1949	1951
McClain, M. H.	1951	1956
Merrill, P. +	1954	1956
Miller, D. H.	1946	1953
Miller, S.	1953	1956
Mixsell, J. W.	1949	1953
Mondrillo, G.	1948	1956
O'Keefe, M.	1951	1953
Pagenhart, T. H.	1952	1956
Patton, C. P. (SIPRE)	1951	1952
Peasley, P. (USBR)	1949	1951
Rantz, S. E. (USGS)	1947	1949
Rhodes, F. L. +	1947	1950
Rockwood, D. M.	1953	1956
Roelle, D.	1949	1950
Sargis, F.	1948	1949
Stark, F. C.	1951	1953
Summers, B. L.	1947	1951
Tarble, R. (USWB) +	1950	1952
Threlkeld, A. F. (USWB)	1951	1952
Walsh, K. J. (SIPRE)	1951	1953
Weimar, M. B.	1947	1956
Williams, C., Jr.	1950	1953
Wilson, W. T. (USWB)	1945	1952

1/ Minimum of one year's continuous service. All employees are Corps of Engineers (CSI) personnel, except as indicated.
2/ See table 2-2 for listing of laboratory directors.
* Some discontinuous service.
\+ Additional time spent in laboratory operation not indicated here.